THE LINK PROJECT: A NOAA and NASA Partnership

E Lindstrom[1], A. McCurdy[2], J. Manley[3], and A.N. Shepard[4]

[1]NASA Oceanography Program Scientist
[2]NASA Oceanography Outreach/EnterACKed
[3]NOAA Office of Ocean Exploration/Mitretek Systems
[4]NOAA Undersea Research Center at the University of North Carolina at Wilmington

http://www.thelinkproject.org

***Abstract* – Edwin Link was a prominent aeronautics and ocean engineer--an inventor and explorer who transcended the boundaries between earth and sky. The National Aeronautics and Space Administration (NASA) is a world leader in technological innovation and invention. The National Oceanic and Atmospheric Administration (NOAA) is a world leader in ocean research and management. The Link Project is designed to breakdown barriers between agencies involved in ocean technology development and exploration. The project has increased the number of jointly managed projects that utilize new approaches to ocean research, exploration and discovery. New outlooks on managing technology programs and greater awareness of available technologies in both agencies are clear outcomes of the Link Project. The individuals and programs connected thus far have begun to understand the challenges and methodologies of their counterparts. Building on this foundation both NOAA and NASA look forward to further exploration of new frontiers.**

I. INTRODUCTION

A. Background

Edwin Link was a prominent aeronautics and ocean engineer--an inventor and explorer who transcended the boundaries between earth and sky. His inventions allow pilots to safely train, sense and respond to the dangers of being airborne (the Link Trainer), and take humans to the bottom of the ocean. With peers such as Jacques Cousteau and George Bond, he set the stage for mixed gas diving and living in the sea. He designed the Johnson-Sea-Link submersibles, which are among the nation's most productive research submersibles in terms of dives performed and innovative scientific applications.

The National Aeronautics and Space Administration (NASA) is a world leader in technological innovation and invention. The National Oceanic and Atmospheric Administration (NOAA) is a world leader in ocean research and management. The Link Project, named after Dr. Link, seeks to join the missions and capabilities of these two agencies, as well as the ocean and space science and technology communities, by crossing boundaries to seek new approaches to ocean research and exploration. Through the Link Project, ocean and space technologists and engineers apply new approaches, resources and technologies to undersea research problems.

The Link Project objectives include:

- Identification of priority areas of mutual interest and partnership opportunities for ocean and space scientists and engineers,
- Promotion of ocean and space exploration, science, and technology development,
- Enhancing the use of cutting-edge technologies for oceanographic research.

The Link Project is designed to breakdown barriers between agencies involved in ocean technology development and exploration. The project has increased the number of jointly managed projects that utilize new approaches to ocean research, exploration and discovery. Technologies identified and emerging partnerships are resulting in new opportunities and capabilities in the arena of ocean exploration and research.

B. Vision

An overarching mission of the Link Project is to facilitate partnerships and technology exchange between the ocean and space communities in both science and engineering by combining the exploration and technology missions of NASA and NOAA.

NASA's Strategic Plan describes its three-part mission across all five of its strategic enterprises:

- To advance and communicate scientific knowledge and understanding of the Earth,

0-933957-31-9

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **01 SEP 2003**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**
4. TITLE AND SUBTITLE **THE LINK PROJECT: A NOAA and NASA Partnership**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **NOAA Undersea Research Center at the University of North Carolina at Wilmington**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002146. Oceans 2003 MTS/IEEE Conference, held in San Diego, California on September 22-26, 2003. U.S. Government or Federal Purpose Rights License., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

- the solar system, and the universe and use the environment of space for research
- To explore, use, and enable the development of space for human enterprise
- To research, develop, verify, and transfer advanced aeronautics, space, and related technologies.

The scientific challenges faced by NASA's five enterprises drive technology decisions and strategies.

As such, technology development at NASA is done in accordance with its Technology Plan. The objective of this plan is to provide a description of the NASA-wide technology program encompassing the content of ongoing and planned activities, as well as the rationale and justification for these activities in the context of NASA's future needs. This plan describes the agency's view of the relationship among technology, scientific research and engineering. "Technology" is the practical application of knowledge that creates the capability to do something entirely new. "Scientific research" encompasses the discovery of new knowledge from which new technology is derived, and "engineering" uses technology derived from this knowledge to solve specific technical problems.

Many of the outstanding contributions to ocean science by NASA involve the newly developed technologies for remote sensing. The advent of precision altimetry has revolutionized global oceanography by providing maps of ocean surface topography, with impacts on oceanographic studies, climate forecasting, fisheries, and many other applications.

Traditionally, NOAA has not had such a well defined focus for its technology programs. Different organizations, in different NOAA line offices, apply their own management principles to technology efforts. Due to the significant pace of operations in major NOAA components, such as the Office of Coast Survey or Nation al Weather Service, technical innovation must take a second place to pressing programmatic demands. A key objective of the Link project is to expose NOAA program managers to NASA's technology development methodologies, as well as NASA's technology portfolio. This cross-pollination will allow NOAA to leverage NASA's significantly larger technology R&D budget and improve its overall technical capacity.

The remainder of this paper provides a synopsis of products and evolving projects resulting from the Link Project. These serve as examples and do not necessarily represent a comprehensive presentation of all collaborative efforts between NASA and NOAA.

II. PROGRAM ELEMENTS

A. Workshops and Meetings

1) Santa Barbara Workshop, 2000 - The Santa Barbara workshop hosted 24 scientists and engineers representing 14 agencies and institutions. Their objective was to identify new ocean robotic technologies including sensors and platforms that are also of interest for space applications. Participants were asked to consider constraints to near-term implementation of the technologies and to recommend opportunities for partnerships.

During the workshop several technologies and technology-areas were targeted for further exploration by ocean and space communities:

- Sensor Webs: Networked, wireless, spatially distributed sensor pods that are deployed to monitor and explore remote environments.
- Semi-autonomous Navigation, Control and Manipulation: Un-tethered vehicles with enough intelligence, power and capabilities to respond to high-level task directives from a remote user.
- Multiple, Cooperating Autonomous Underwater Vehicles (AUVs): Multiple systems that offer the ability to obtain higher-resolution and more complex temporal and spatial sampling, as well as greater adaptive control and redundancy.
- In situ Sensors Sampling, Calibration, and Verification: Long-term measurement sensors capable of performing specific tasks in a diverse set of environments that also offer routine calibration and data validity checks without the need for instrument recovery.
- Underwater Imaging for Characterization, Mapping and Positioning: Instruments that allow for more detailed, wide area, three dimensional mapping that will enable a mobile robot to build a map of an unknown environment, while simultaneously using that map to navigate.

2) Kennedy Space Center Symposium, 2002 - Following the success of the first workshop, plans were launched to conduct a second workshop with broader objectives designed to foster sea and space exploration education and outreach as a primary goal. The result was a second Link Project workshop held at the Kennedy Space Center, May 2002. Over 100 attendees participated in the three-day meeting. (A complete description of the symposium objectives and recommendations is included in Shepard et al., 2002).

Each presentation and technical session focused on identifying critical research needs, areas of overlapping interest, and the development of

promising new technologies. Key technology related recommendations included: [1]

Sensors and Tools:

- Avoid duplication of effort across multiple funding agencies through development and use of a Web-based database/inventory of sensors and tools, including data mining effort for new technologies.
- Promote development of sensor standards (e.g., calibration, procedures) and require that future funding of sensor development be contingent upon compliance with standards.
- Build partnerships with space organizations to develop better management approaches for vast amounts of ocean data anticipated from new sensor and platform technologies.

AUVs:

- Develop better navigation capabilities, particularly for high-latitude operations, where measuring heading is difficult and expensive.
- Improve reliability and self-maintenance of AUVs on long-term deployments (e.g., from observatories), including development of docking, battery recharge, and Artificial Intelligence (AI) software that can recognize potential mission failure modes, mitigate against failures, and initiate self-repairs.
- Partner with engineering groups engaged in advanced robotics research, for example, to develop fractal robots.
- Increase support for facilities and programs that provide access to AUVs and sophisticated AUV payloads to a broader user community.
- Hold more focused meetings to address specific science-driven technology needs such as AI, power, communications, payload modularity, sampling strategies, and navigation.
- Coordinate payload (sensors and tools) technology developments across multiple agencies, in part through development of a technology database and interface standards.
- Support institutions with *in-situ* resources to accommodate trials for promising new technologies at low cost.
- Develop and utilize a full ocean depth AUV as a sensor development laboratory in support of new ocean exploration initiatives and evaluation of sensors in earth environments similar to those found in space.

Human Exploration:

- NOAA should begin immediate planning to increase the size of the *Aquarius* undersea laboratory at its next overhaul, and provide support for increasing the number of missions done per year.
- NOAA should begin planning for a shallow water family of habitats (0-65 m), so that at the end of 5 years there will be seafloor habitats of the *Aquarius*-type (with upgrades) at several sites in U.S. waters.
- Develop and refine *rebreather* technologies toward simplified, user-friendly systems.
- Improve communication between commercial, scientific and navy divers, for example, through a forum that enables sharing information and experience.

B. Education and Outreach

1) Education Strategy - Ocean exploration and technology development are exciting ventures with endless potential for educational opportunities. As such there have been several educational outcomes from project activities. Project steering committee members drafted an education strategy to guide the ongoing creation of education projects funded in conjunction with Link Project activities.

The Link Project educational products will:

- Relay the relevance of the oceans to our everyday lives,
- Impart how history and the nature of technology development has had an impact on society,
- Create an awareness and understanding of science and technology development as continuous processes,
- Teach how technology enables exploration in extreme environments,
- Develop an understanding of the impacts of exploration technologies on organisms and the environment,
- Develop an understanding of the importance of sustained funding to build technologies that answer ever-changing scientific questions.

2) Web Site - The Link Project web site (http://www.thelinkproject.org) was developed to chronicle project activities as well as to serve as a meeting place for scientists, technologists, engineers, teachers, students, and the general public. The site hosts workshop and symposium reports, related articles and the archives of symposium web cast events.

The web site features archives of web cast events of the 2002 Symposium. During the symposium the NASA Telescience Lab at KSC provided web casting of the plenary sessions and keynote addresses held at the conference center.

3) MATE ROV Competition - In conjunction with the 2002 Link Symposium, the Marine Advanced Technology Education Center (MATE), (http://www.marinetech.org) hosted its first national ROV competition at Kennedy Space Center and Brevard County Community College. Twenty-two

high school, community college, and university teams from ten states and Canada, competed in design judging and an underwater competition.

The competition was part of a national effort to introduce students to marine science and technology and help them develop the technical, problem solving, and teamwork skills needed in the marine technology workplace.

Fig. 1. 2002 MATE ROV competition participants

The competition also facilitated connections among students, educators, and professionals from industry. Thirty-three organizations donated funds, equipment, supplies, and facilities, while more than 30 professionals volunteered their time as mentors, advisors, and competition.

C. Science and Technology Projects

1) SensorWeb Deployment - At the 2000 meeting, NASA Jet Propulsion Lab experts presented the SensorWeb concept, a series of low-cost, networked, in situ sensor packets originally intended to be spread over another planet's surface.

A SensorWeb is now being tested in a lagoon at the Kennedy Space Center for assessing water quality and physical conditions. A related meeting was held in 2001 at NOAA headquarters and several programs expressed interest in the technology for ecosystem monitoring.

2) Oculina Mission – Pursuant to informal talks at the 2002 symposium, ocean scientists, NASA engineers, and the United Space Alliance cooperated on two ocean research projects to the Oculina Banks marine protected area 20 miles offshore from Cape Canaveral utilizing NASA KSC shuttle support vessels. The support ships M/V Liberty Star and M/V Freedom Star are normally operated by the United Space Alliance for shuttle solid rocket booster recovery.

In October 2002, the ships conducted a multi-beam echosounder survey to create a new chart of most of the Oculina habitat in the reserve. In April 2003, they returned with a remotely operated vehicle to explore the new chart. Also, on the spring cruise, a Passive Acoustic Monitoring System developed by NASA engineers to monitor shuttle launch sounds in the wildlife refuge lagoons on the grounds of KSC, was deployed and tested offshore to detect and locate fish aggregations and vessel activity. The PAMS units may one day be used to monitor recovery of fish stocks and help enforce the ban on groundfishing in the Oculina Banks reserve. [2]

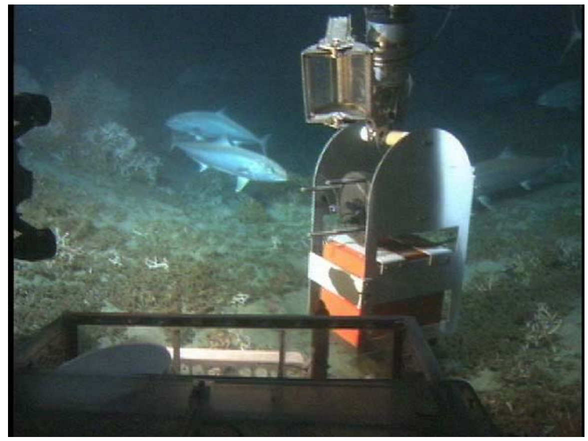

Fig. 2. A PAMS unit at sea

3) Joint Technology Demonstrations – Recognizing the unique facilities and natural environment at the Kennedy Space Center an inter-agency team is working to establish a long term cooperative technology development and test program at KSC. NOAA, NASA, Navy, and USCG elements are bringing together technology research programs focused on the interrelated themes of environmental stewardship, research and monitoring, and security. A pilot program is planned for August of 2003. This effort will combine KSC’s marine infrastructure with Navy technologies, notably autonomous underwater vehicles and marine mass spectrometers. Engineers and technology program managers from all four agencies will participate and share in the experience. This small-scale effort is expected to expand into more significant collaborative programs in 2004 and beyond.

III. LOOKING FORWARD

Since the first Link Project workshop in 2000, NASA and NOAA collaboration has increased dramatically. A “cultural exchange” between the agencies is already bearing fruit. New outlooks on managing technology programs and greater awareness of available technologies in both agencies are clear outcomes of the Link Project. Additional

direct technology exchange is anticipated in the future.

Within NOAA, the Office of Ocean Exploration (OE) anticipates a significant benefit from collaborative NOAA/NASA activities. The report of a presidential panel on ocean exploration (which inspired NOAA to create OE) highlighted "developing new sensors and systems for ocean exploration" as a key focus of the nation's ocean exploration program. [3] OE envisions two key areas of exploration technology which will benefit from the Link Project.

Robotic systems are powerful tools for exploring hostile environments. From the far reaches of space to nuclear power plants, robots go where human explorers and scientists cannot. The deepest reaches of the ocean, beyond 10,000 meters are one of the least visited places on earth. OE hopes that collaboration between marine and space robotics programs will improve access to both outer and inner space. The ultimate expression of such collaboration might be an exploration of the waters thought to lie beneath the icy surface of Europa.

New sensors are another area where ocean and space technology can come together. Physical, chemical, biological, and geological features, on another planet or the bottom of the ocean, are of interest to all scientific exploration. NASA's expertise in designing sensors capable of withstanding the rigors of launch and functioning reliably, sometimes for years, will be of great benefit to ocean explorers. The dynamic environment of the ocean, from coral reefs to deep vents, provides ample opportunities for new sensor technologies to be tested and proven before they are deployed to space.

The long-term benefits of collaboration between the space and ocean science and technology communities are apparent. As the Link Project has progressed, these two communities have been brought closer together. The individuals and programs connected thus far have begun to understand the challenges and methodologies of their counterparts. Building on this foundation both NOAA and NASA look forward to further exploration of new frontiers.

Acknowledgments

The authors would like to acknowledge the support of their colleagues throughout the ocean and space research communities. Many scientists and researchers have demonstrated their commitment to collaborating in innovative ways. The Link Project activities have been funded by, among others, the NASA Oceanography Program, The NOAA Office of Ocean Exploration, the National Marine Sanctuary Program, and NOAA Undersea Research Program..

References

[1] Shepard, A.N., P. Fryer, J. Bellingham, B. Moore, M. Kelly, J. Zande, A. McCurdy, J. Carless, M. Ward, and L. Lemmerman. 2002. Link 2002 symposium: Sea and space experts join to develop undersea technologies, held 20-22 May 2002 at NASA Kennedy Space Center, Cape Canaveral, Florida. Mar. Tech. Soc. J. 36(2): 70-77.

[2] (http://oceanica.cofc.edu/oculina2003/home.htm)

[3] *Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration*, Report of the President's Panel on Ocean Exploration, University Corporation for Atmospheric Research, 10 October 2000.